AS Unit 1: Basic Biochemistry and Cell Organisation

Name:	Date:

Topic 1.1 Biological Compounds – Page 3

I. Carbohydrates

		Completed
1.	Go through the PPT on Carbohydrates	
2.	Read the following handouts: • 1.1E Glucose BSR • 1.1F Soluble Carbohydrates • 1.1G Getting to Grips with Structures • 1.1H Structure and Function of Polysaccharides • 1.1I Polysaccharides • 1.1J Carb Revision	
3.	Complete the questions on H/O 1.1K Carbohydrates	
4.	Homework: Be able to draw and talk about the structure of the following: • α and β glucose, both straight-chain and ring forms • Maltose and be able to show how it is formed • Starch • Cellulose • Chitin • Glycogen	

Carbohydrates

General features:

Organic compounds which contain the elements _________________,
_____________ and ________________.

Carbohydrate type	Examples	Characteristics	Role in living organisms

Classification of monosaccharides (monomers)

Use the notes to complete the following:

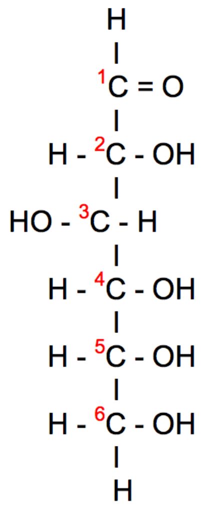
	Trioses ($C_3H_6O_3$)	Pentoses ($C_5H_{10}O_5$)	Hexoses ($C_6H_{12}O_6$)
Number of carbons			
Examples			

Structure of Monosaccharides and numbering the carbons

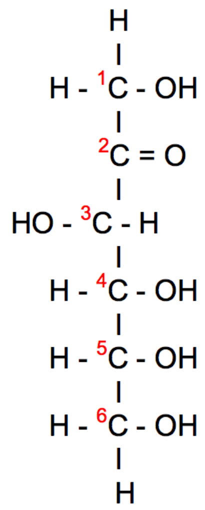
Monosaccharides contain either an aldehyde group (-CHO) or a ketone group (C=O). Monosaccharides may exist as chain or ring forms.

Carbon atoms are numbered in monosaccharides to allow for ease of communication when describing where bonds form between other molecules.

In the straight form numbering starts from the carbon atom nearest the aldehyde (-CHO) or ketone (C=O) group. Highlight and label a ketone and an aldehyde group below:

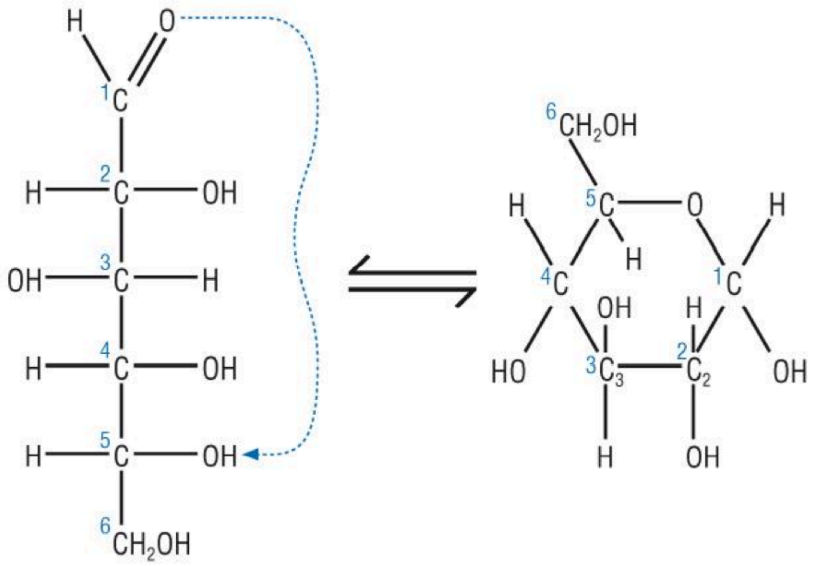


glucose



fructose

Monosaccharides can exist in a ring form and a straight chain form.



Glucose chain form

α Glucose ring form

Monosaccharide Isomers

Monosaccharides can exist as a number of **isomers** (they possess the same molecular formula but differ in the arrangement of atoms). Different isomers arise when a carbon atom has four different groups attached to it. This is called an **asymmetric carbon atom**. An asymmetric carbon atom arises when glucose forms a ring form, two isomers arise ɑ and a β form.

Use your notes to complete the following:

Highlight the four different groups that are attached to carbon 1 and give rise to the asymmetric carbon atom.

ɑ glucose	β glucose

Disaccharides

Draw a diagram to show a condensation reaction between 2 α glucose molecules. Clearly label the glycosidic bond.

Complete the table below to summarise the information about 3 common disaccharides.

Disaccharide	Monomer 1	Monomer 2	Use in Living Organisms
Maltose			
Sucrose			
Lactose			

Polysaccharides

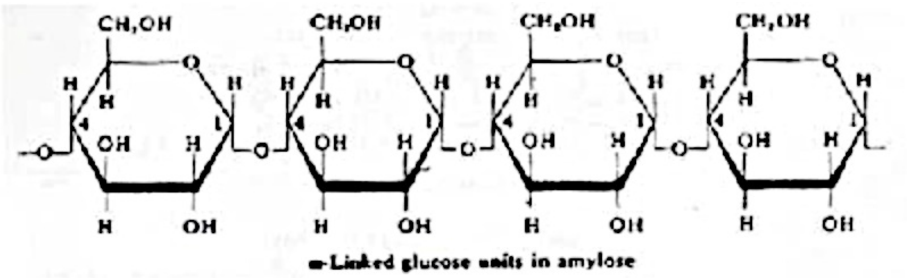
Condensation polymerisation between many monosaccharides will give rise to polysaccharides. The number of monosaccharides that combine varies and the chain produced, whether it is straight or branched etc. depends upon to monomers that are condensed.
Polysaccharides are large insoluble molecules and thus exert no osmotic effect. They may also be folded and this will make them ideal molecules for compact energy storage.

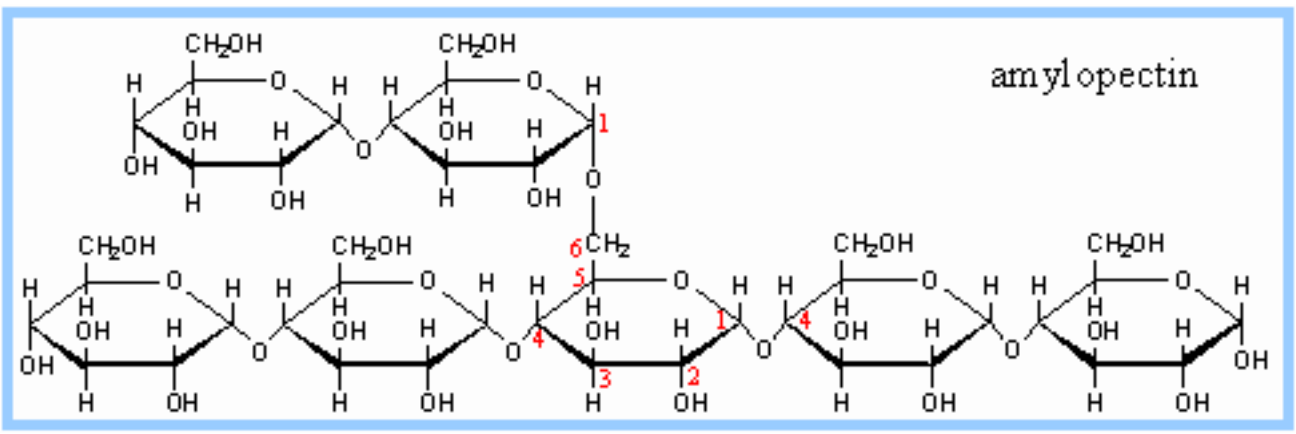
Most of the important polysaccharides are made from hexose units, many from just glucose itself.

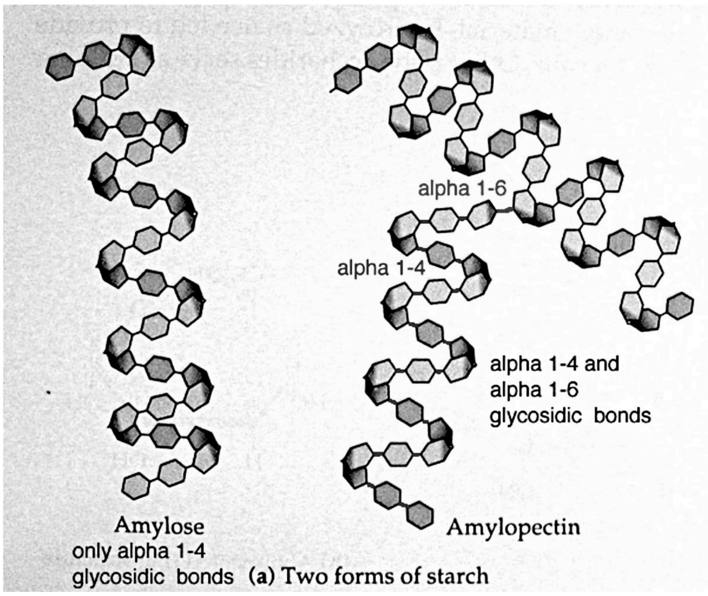
Starch

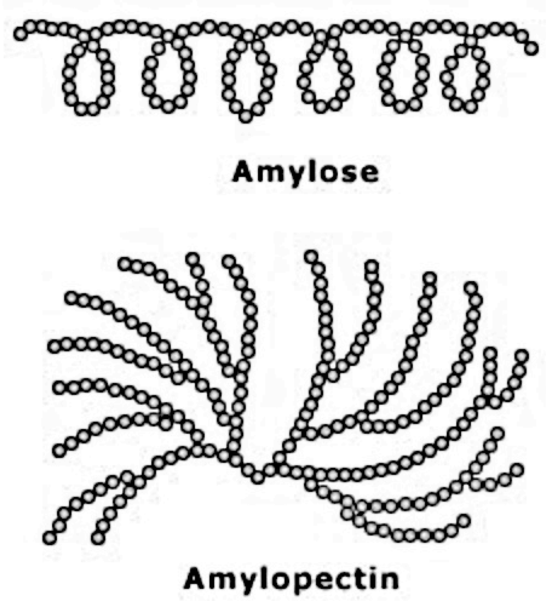
Found in plant cells as granules. Starch is a mixture of two polymers **amylose** and **amylopectin**. **Amylose** is an unbranched polymer in which glucose molecules are joined by α-1, 4-glycosidic linkages. These bonds bring the monomers together at a slight angle and when repeated many times a spiral molecule results.

The glucose chains of amylopectin have α-1, 4-glycosidic linkages and α-1 6-glycosidic linkages, this allows branching.



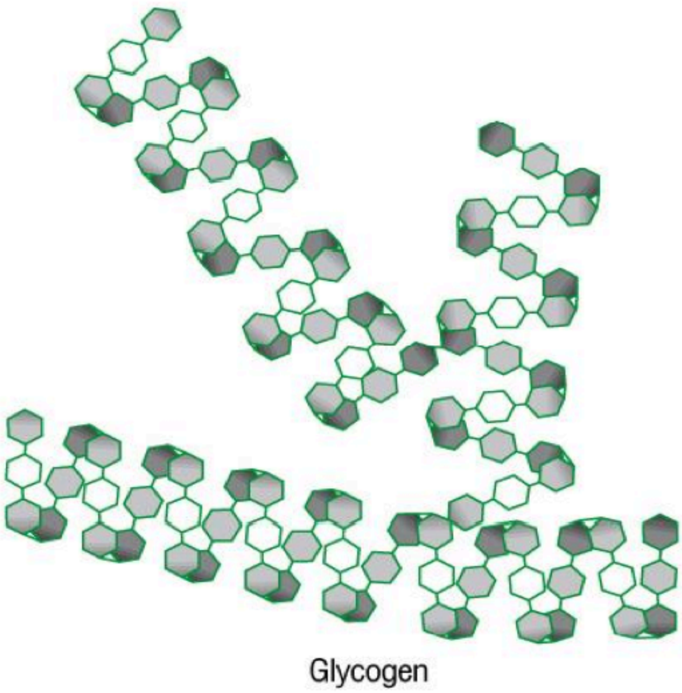






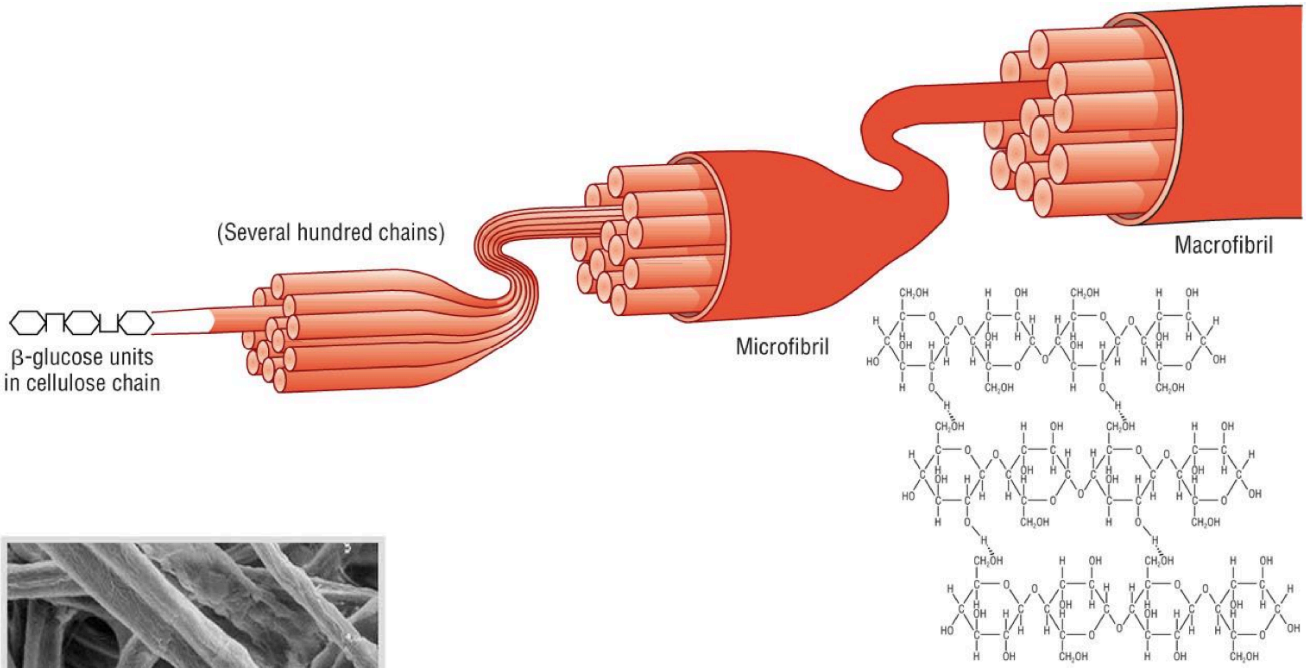
Glycogen

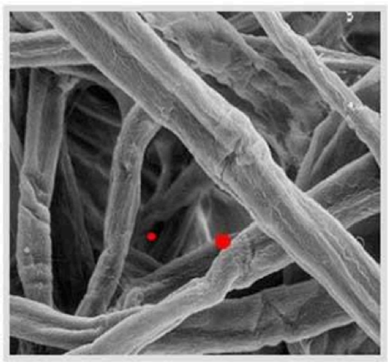
In animals glycogen is the main storage carbohydrate.
Its structure is similar to amylopectin but it is even more branched.



Cellulose

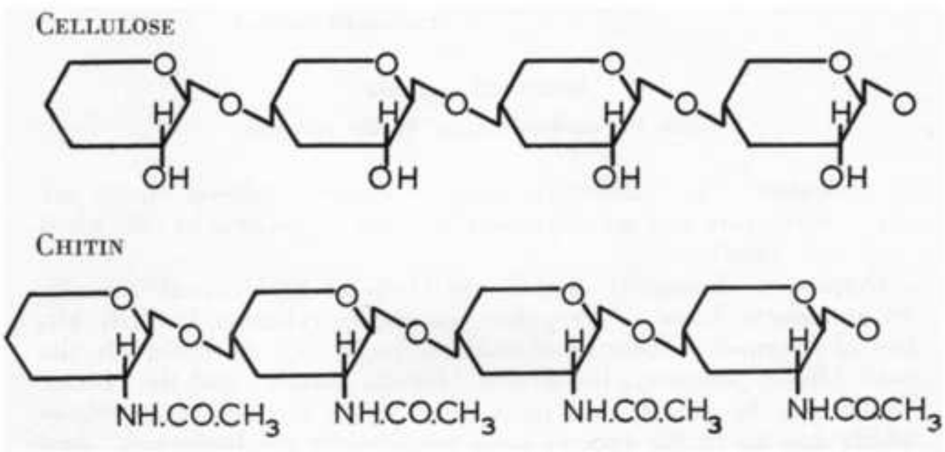
Cellulose is a structural polysaccharide. Individual cellulose molecules are formed from many β-1,4-glycosidic linkages. Each glucose added to the polymer rotates 180 degrees and this allows hydrogen bonds to form between the hydroxyl (OH) groups of adjacent parallel chains.





Chitin

Chitin resembles cellulose. It differs in possessing an acetyl-amino (glucosamine) group ($NH.OCCH_3$) instead of one of the hydroxyl (OH) groups. It has a structural function in the exoskeleton of arthropods and fungi cell walls.



Looking at the functions of Carbohydrates

Energy

Glucose units contain a lot of bonds that can be broken down to release energy during respiration to create ATP. The breakdown occurs in a series of steps that are driven by shape-specific Enzymes. In plants and animals, only α glucose can be broken down in respiration as only the enzymes which fit its shape are present.

α Glucose can form long chains with thousands of subunits called and Amylose molecule. Glucose units are bonded together by Condensation Reactions forming (1→4) Glycosidic Bonds. Amylose molecules tend to form coiled springs due to the way in which the glucose units bond, making it quite compact. Large molecules such as amylose differ from glucose in that they are not water soluble.

Iodine molecules can become trapped within the 'coils' of the Amylose chain, which causes iodine (in Potassium Iodide solution) to change colour from yellow-brown to blue-black.

Starch consists of a mixture of Amylose and a branched carbohydrate chain called Amylopectin. The branches are formed when a one end of a chain joins with glucose in another, forming a (1→4) Glycosidic Bond.

Glycogen is almost identical to starch but differs in that the chains of (1→4) linked glucoses are shorter, giving it a more highly branched structure. This branching allows for the fast breakdown of the molecule during respiration as it means that there are more ends which enzymes can start the process of hydrolysis from.

Structural

β Glucose chains, like the one above, are called Cellulose molecules, and can contain 10000 glucose units. They are stronger than Amylose and are only found in plants. Cellulose is the most abundant polysaccharide found in nature.

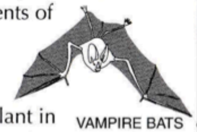
Cellulose fibres are arranged in a very specific way and can be described as being like a fractal. Long Cellulose chains bunch together, held by Hydrogen bonds, to form Microfibrils. These Microfibrils are bunched with other Microfibrils, held by more Hydrogen bonds, to form Macrofibrils.
Macrofibrils have a very high mechanical strength, similar to that of steel. In plant cell walls, they criss-cross over each, forming a cross-hatched structure, held by Hydrogen bonds, which is very strong. This also allows water to move though and along the cell wall. The strength of the cell walls prevent the cell form bursting, as it would in an animal cell, when water passes into the cell. The pressure cause by the water makes the cell Turgid, supporting the plant through Turgor Pressure.
Microfibrils can have special roles. *For example, in Guard Cell Walls, the arrangement of microfibrils allows the Stomata to open and close.* Cell walls can also be reinforced with other substances, or made waterproof.
Other Carbohydrate Polymers are used by a number of other organisms to provide support, *such as Peptidoglycan, which forms the basis of bacterial cell walls, and Chitin, which makes up the exoskeleton of insects.*

Functions of soluble carbohydrates include transport, protection, recognition and energy release.

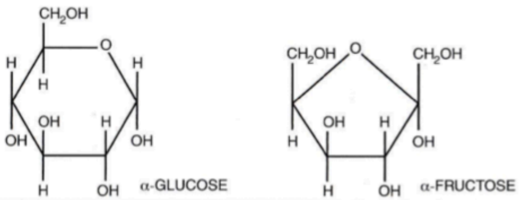
1.1F Soluble Carbohydrates

Glucose is the most common substrate for respiration (energy release).
Fructose is a constituent of nectar and sweetens fruits to attract animals and aid seed dispersal.

Sugar derivatives include *sugar alcohols*, e.g. glycerol, *sugar acids*, e.g. ascorbic acid, and *mucopolysaccharides*, which are important components of connective tissues, synovial fluid, cartilage and bone. Heparin (anticoagulant in blood) is derived from mucopolysaccharides and has a protective function.

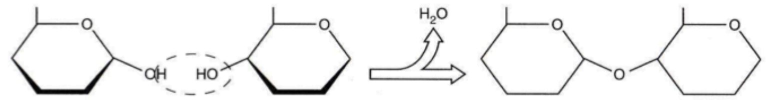


Glucose and fructose are both **monosaccharides** (single sugar units) with the typical formula $C_nH_{2n}O_n$. They each have **six carbon atoms** and are thus called **hexoses** (**pentoses** have 5 carbon atoms and **trioses** have 3).
Glucose and **fructose** are isomers of $C_6H_{12}O_6$.

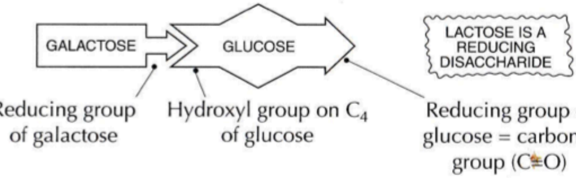


Oligosaccharides are short (often 6-12 units) condensation products which combine with protein (*glycoprotein*) or lipid (*glycolipid*) and form the outer coat (*glycocalyx*) of animal cells. They are important in *cell-cell recognition* and the *immune response*.

In naturally occurring **disaccharides** monosaccharide rings are joined together by *glycosidic bonds*.

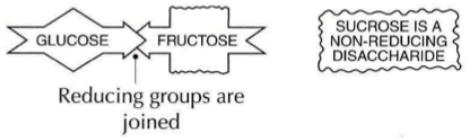


This most usually occurs between *aldehyde* or *keto group* (i.e. the reducing group) of one monosaccharide and an *hydroxyl group* of another monosaccharide, e.g. *lactose*.

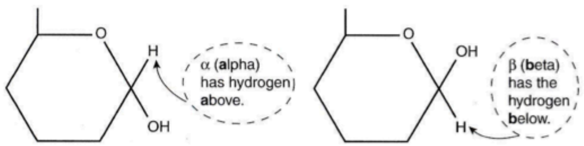


(*Maltose* is a reducing disaccharide formed from two molecules of α-glucose.)

More rarely it can happen between *reducing groups of adjacent monosaccharides*, e.g. *sucrose*.



α-glucose and β-glucose are isomers. These two molecules only differ in the arrangement of –H and –OH at the first C atom in the 'ring'.



Lactose intolerance occurs in many adults. This results from a deficiency in *lactase* so that dietary lactose accumulates in the lumen of the small intestine. This lowers the water potential of the gut contents causing an influx of fluid into the small intestine - this results in abdomenal distension, nausea, pain and diarrhoea. The condition is much more common in adult populations for whom milk is an unusual or uncommon food.

Sucrose (*glucose-fructose*) is the main transport compound in plants. Commonly extracted from sugar cane and sugar beet and used as a sweetener.

Lactose (*glucose-galactose*) is the carbohydrate source for suckling mammals - milk is about 5% lactose.

Bio Factsheet

www.curriculum-press.co.uk Number 159

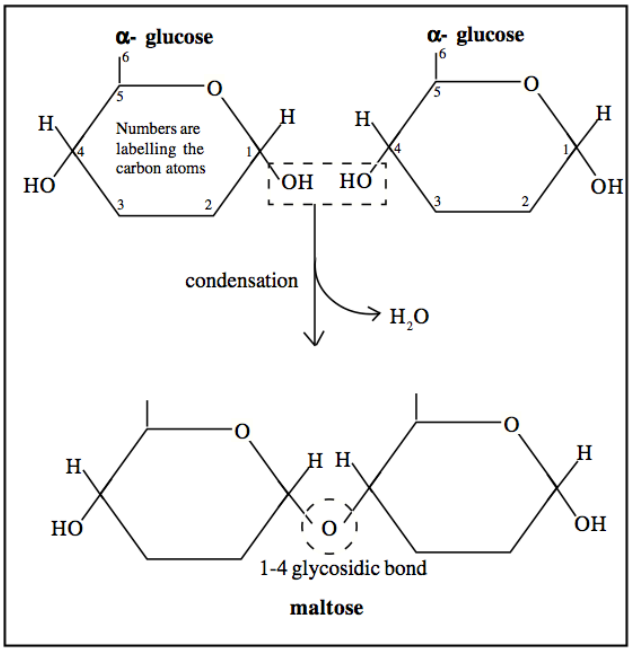
The Structure and Function of Polysaccharides

This Factsheet summarises:
- The structure of the polysaccharides starch, glycogen and cellulose.
- The functions of polysaccharides.
- How structure is related to function.

Structure

The key points are:
- Polysaccharides are organic molecules made up of carbon (C), Hydrogen (H) and Oxygen (O).
- They are polymers ie they are large molecules (macromolecules) made up of simple units (building blocks) repeated many times.
- Glucose is the commonest monomer from which the macromolecule or polymer is formed.
- These simple units –or monomers – are held together by bonds formed in condensation reactions in which a molecule of water is formed as two monomers are joined .
- These bonds are called glycosidic bonds (Fig1).

Fig 1



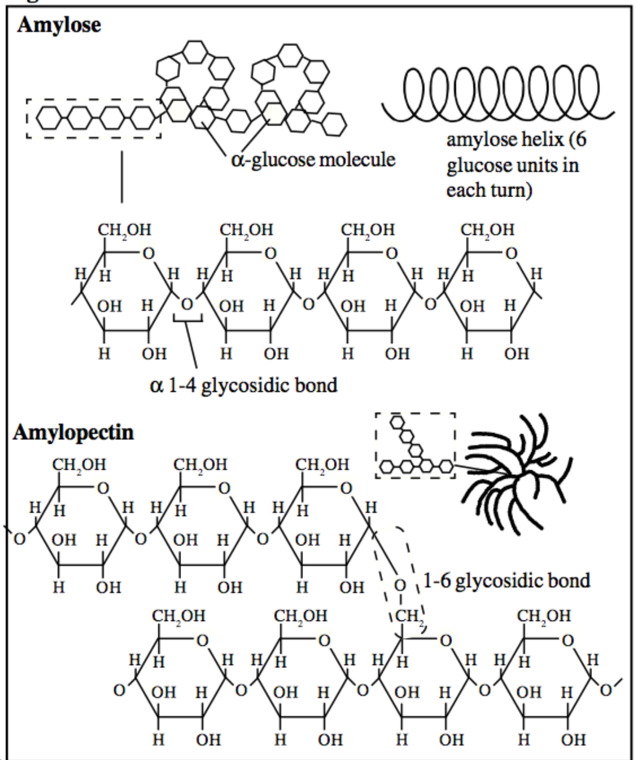
The polysaccharides that come up repeatedly in the exams are starch, glycogen and cellulose.

> **Typical exam questions on this topic**
> - Outline what is meant by a condensation reaction or draw/ label a diagram showing the reaction.
> - Explain how structure fits function in eg starch, glycogen and cellulose.
> - Describe in extended prose the significance of polysaccharides in animals and plants.
>
> Occasionally, you might be asked to comment on the biological significance of other polysaccharides – chitin, for example, but because these aren't specifically mentioned in any specification you can usually just make up something which is biologically sensible –we'll explain this later on in the Factsheet.

Starch

Starch is a polymer of α-glucose.
It is a mixture of two substances: amylose and amylopectin.
Typically, starch = 20% amylose, 79% amylopectin and 1% phosphates/fatty acids but the precise composition varies between species (remember starch is **only** found in plants).
Amylose and amylopectin have very different structures (Fig 2).

Fig 2.



Amylose
Alpha-glucose molecules form an unbranched chain that coils itself into a helix (like a spring).
Significance of this? The helix is compact, making it a good storage molecule.
The glucose molecules are joined by 1-4 linkages (meaning that carbon atom 1 of one glucose molecule links with carbon atom 4 of the next glucose molecule).

Amylopectin
Alpha-glucose molecules form long, branched chains.
Significance? Long chains means few "ends" making amylopectin difficult to break down = good for storage.
The glucose molecules within the branches are 1-4 links (as in amylose) but where the branch joins the main chain, a 1-6 link forms.

The mixture of amylose and amylopectin is built up into large starch grains in potato tubers, many seeds and the stroma of chloroplasts, where they act as energy stores.

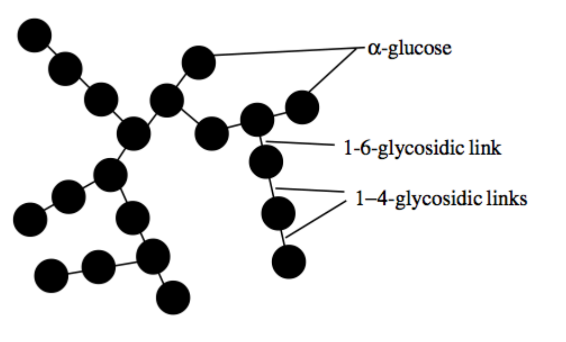
Exam questions don't usually ask you explicitly about the way in which the structure of amylose and amylopectin fit their function, rather they usually expect you to mention these details when asked about starch as a whole. So remember:

- starch is compact = good for storage.
- insoluble = osmotically inactive.
- too big to pass through membranes = inactive/good for storage.
- provides many glucose molecules = good respiratory substrate.

Exam Hints
Many candidates mistakenly appear to believe that:
1. *Long chains of starch provide support. They had clearly confused the roles of starch and cellulose.*
2. *Starch stores something else – inside its helix.*
3. *Starch is soluble.*
4. *Cell walls are made of starch.*

Glycogen
α- glucose polymer.
Branched like amylopectin but has shorter 1,4 chains and many more branches (Fig 3).

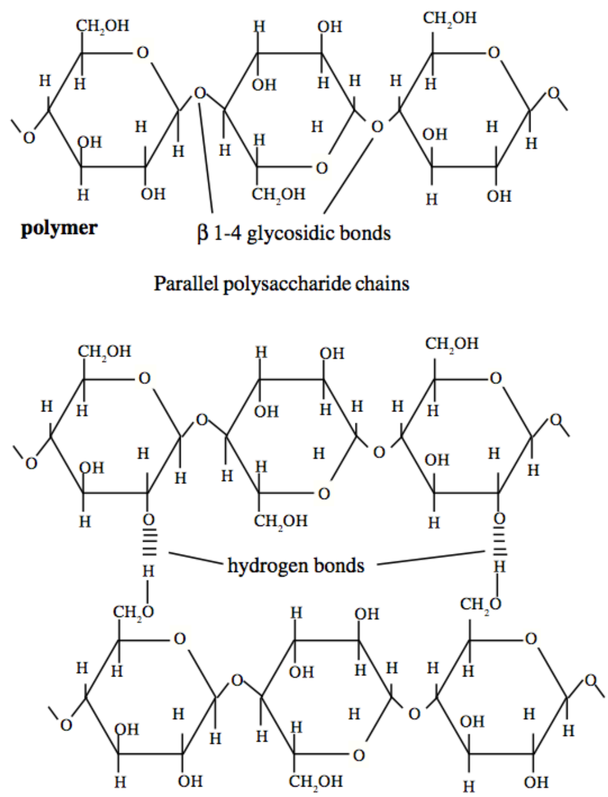
Fig 3. Glycogen



Significance? More branches and shorter chains = more "ends" = faster to breakdown when energy is needed. Whereas starch is the storage molecule in plants, glycogen is the store in animals, fungi and bacteria that may suddenly need to release their stores.

In humans, glycogen is stored mainly in the liver and muscles and is important in helping to regulate blood glucose levels.

Cellulose (Fig 4)



Polymer of beta glucose arranged in long, straight chains.
Whereas starch and glycogen are storage molecules, cellulose is a structural polysaccharide.
Cellulose is mechanically strong because:
(i) the inverted arrangement of successive glucose molecules means that thousands of hydrogen bonds form.
(ii) cellulose molecules are tightly cross-linked to form microfibrils
(iii) the microfibrils form fibres.

Within plant cell walls the fibres are arranged in layers running across each other, are interwoven and these layers are held or "glued" together by a matrix of other substances.

Significance?
Cellulose cell walls need to be strong to maintain turgidity so that leaves are held in a position to absorb maximum sunlight.
Stems remain flexible but firm in winds etc.
The gaps in the walls allow permability.

Critisms of students answers
Roles of starch and cellulose in plant cells are often confused.
Some candidates believe that the cell walls of prokaryotes are made of cellulose. They are made of murein.
Many candidates mistakenly suggest that cellulose is the storage carbohydrate that is hydrolysed to glucose to provide the plant with energy.

Candidates often confuse the 3-D structure of celluose and starch with the beta - pleated sheets of proteins.

Fundamental errors seen in recent papers
- *both starch and cellulose are proteins.*
- *that starch is essential for photosynthesis.*
- *that cellulose absorbs light.*

Chitin
Polymer of N – acetylglucosamine
Like cellulose, it has β 1-4 glycosidic links

Significance? Very strong structural component of the exoskeletons of arthropods (e.g. insects and crustacea).

Summary

Storage
- Plants — *Starch*
- Animals, fungi and bacteria — *Glycogen*

Both compact ∴ good use of space.
Both insoluble ∴ no osmotic/ water potential effect.
↓ Hydrolysis
Glucose = high energy respiratory substrate.

Structural
- Plants — *Cellulose*
- Arthropods — *Chitin*

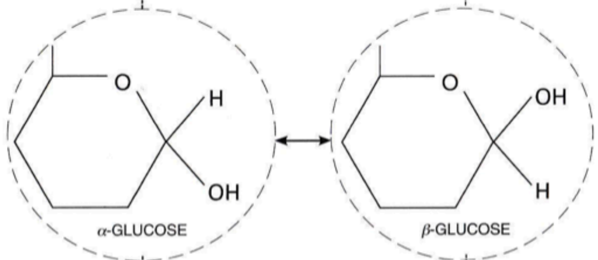
Both mechanically strong to provide protection and in the case of plants, to maintain turgidity.
↓
Cellulose permeable to allow gas exchange for photosynthesis/ respiration.

Typical exam questions

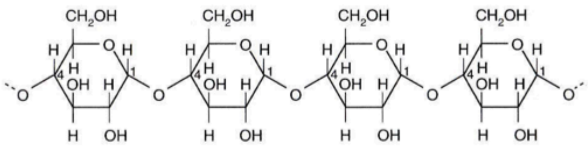
1. Fill in the table –type questions. Place a tick in the box if the statement is correct, place a x in the box if it is incorrect.

Statement	Starch	Cellulose	Glycogen
Storage molecule in plants			
Polymer of beta glucose			
Strengthened by thousands of hydrogen bonds			
A mixture of two polysaccharides			
Only found in fungi			

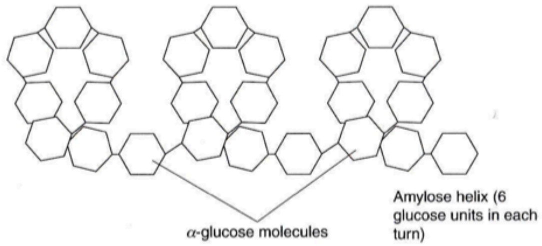
Polysaccharides are polymers formed by glycosidic bonding of monosaccharide subunits. The structure of these molecules affects their functions in living organisms.



Starch is a mixture of two polymers of α-glucose. The most common is **amylose** which usually contains about 300 glucose units joined by α 1,4 **glycosidic bonds**



The bulky $-CH_2OH$ side chains cause the molecule to take up a helical shape (excellent for packing many subunits into a limited space).

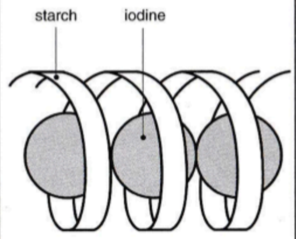


Because there are so few 'ends' within the starch molecule there are few points to begin hydrolysis by the enzyme **amylase**. Starch is therefore an excellent long-term **storage compound**.

All those coils let you test for starch!

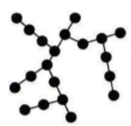
Add a drop of iodine solution (iodine in potassium iodide solution)

positive result (blue-black colouration) = ***starch present***



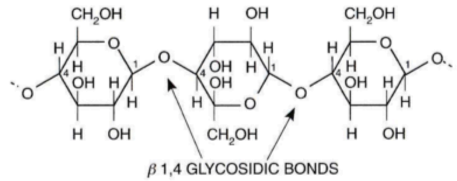
Principle: iodine binds to the centre of the starch helix, forming a starch-iodine complex which is intense blue-black in colour.

Glycogen is an α-glucose polymer, but with many cross-links and shorter α 1,4 chains.

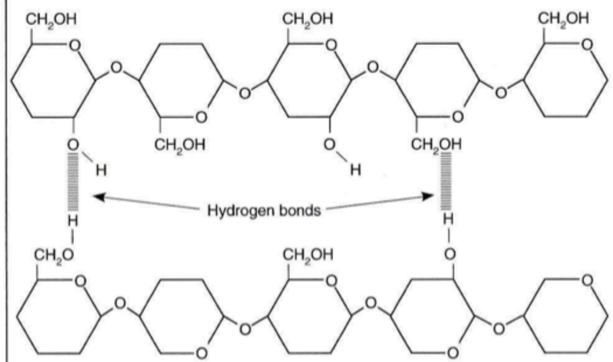


This gives more 'ends' to the molecule which is ideal for animal cells which may need to hydrolyse food reserves more rapidly than plant cells would do.

Cellulose is a polymer of glucose linked by β 1,4 **glycosidic bonds.** The β-conformation inverts successive monosaccharide units so that a straight chain polymer is formed.

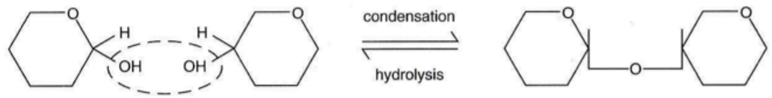


The parallel polysaccharide chains are then cross-linked by **hydrogen bonds.**



This cross-linking prevents access by water, so that cellulose is very resistant to hydrolysis and is therefore an excellent **structural molecule** (cellulose cell walls): ideal in plants which can readily synthesise excess carbohydrate.

Subunits are joined by **condensation** (**removal** of the elements of water) and separated by **hydrolysis** (bond breakage by **adding** the elements of water)



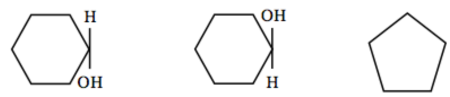
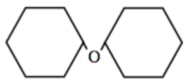
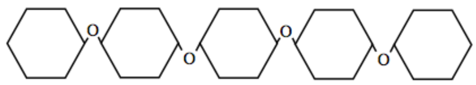
Bio Factsheet

Number 39

Carbohydrates: Revision Summary

Carbohydrates contain 3 elements: Carbon (C), Hydrogen (H) and Oxygen (O). Thus, if we remove water from carbohydrates, all that remains is carbon. Carbohydrates can be divided into 3 categories; monosaccharides, disaccharides and polysaccharides (Table 1).

Table 1. Structure of monosaccharides, disaccharides and polysaccharides

Category	Example	Site	Structure
Monosaccharide (made of 1 sugar molecule)	glucose fructose galactose	fruit fruit, nectar milk	 α-glucose β-glucose fructose
Disaccharide (made of 2 monosaccharides joined together)	maltose = α-glucose + α-glucose sucrose = glucose + fructose lactose = glucose + galactose	germinating seeds phloem tissue, fruit milk	 maltose
Polysaccharide (made of many monosaccharides joined together)	starch = polymer of glucose glycogen = polymer of α-glucose cellulose = polymer of β-glucose chitin = polymer of glucosamine (glucose with an amino acid attached)	chloroplast stroma muscle cells plant cell wall exoskelteton of arthropods	 cellulose

Monosaccharides and Disaccharides

Monosaccharides and disaccharides are **sugars**. They all have the basic formula $(CH_2O)_n$ and can be classified according to how many carbon atoms they contain.

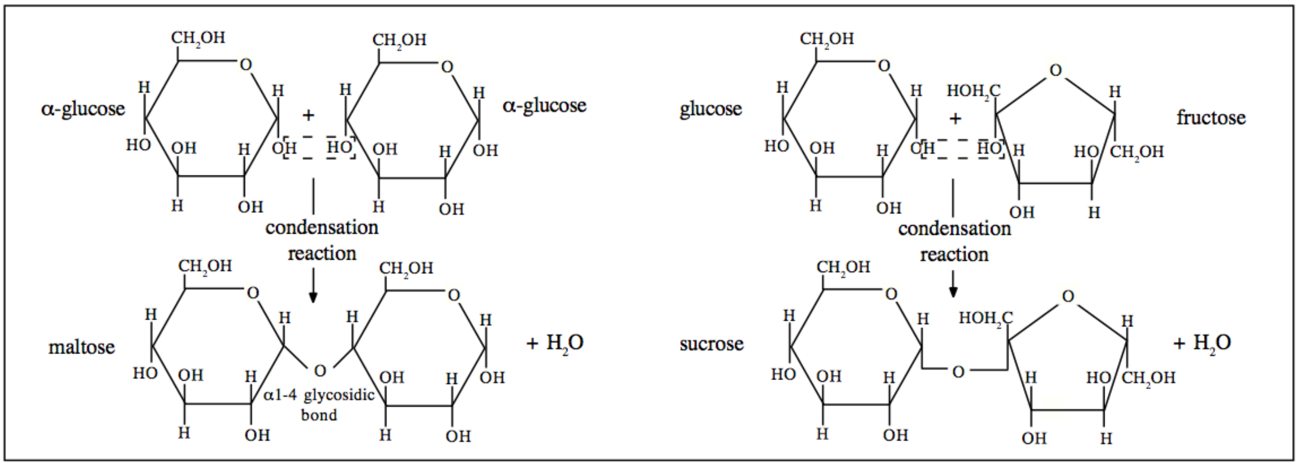
3C = **tri**ose sugars e.g. glyceraldehyde $C_3H_5O_2$
5C = **pent**ose sugars e.g. ribose $C_5H_{10}O_5$
6C = **hex**ose sugars e.g. glucose $C_6H_{12}O_6$

Formation of disaccharides - typical exam questions

Common exam questions include:
1. Name the reaction involved when a disaccharide is formed
2. Name the type of bond formed
3. Show, by drawing a diagram, how a disaccharide is formed

Questions 1 and 2 are very simple - Disaccharides form in a condensation reaction which forms a glycosidic bond. The only way to get Question 3 correct is to practice! Fig 1 shows how maltose and sucrose are formed from their monosaccharides.

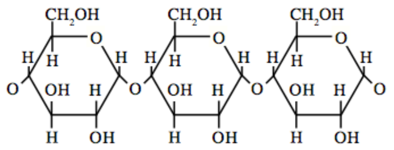
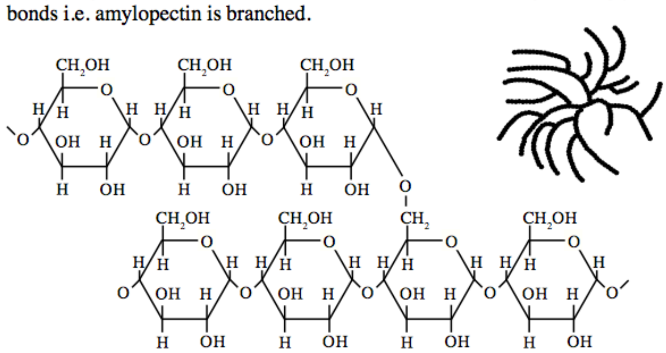
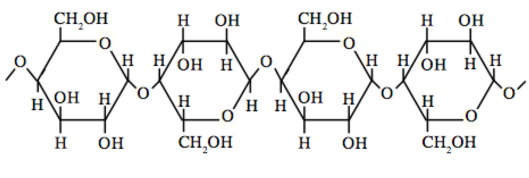
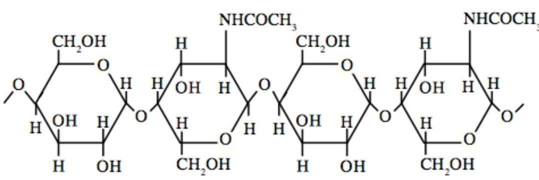
Fig 1. Formation of maltose and sucrose from their monosaccharides



Polysaccharides

Polysaccharides are polymers i.e. they are made up of many repeating units. Three polysaccharides which commonly feature in exam questions are starch, cellulose and glycogen. By far the most common question asks "How is the structure of polysaccharides related to their function?". It should be noted that all 3 have the advantage that they are insoluble in water and therefore have no osmotic effect i.e. effect on water potential and are unable to diffuse out of the cell. More specific features are summarised in Table 2.

Table 2. Structure:Function of polysaccharides

Polysaccharide	Structure	Structure:Function
Starch – Main storage polysaccharide in plants.	Made of two polymers of α-glucose; amylose and amylopectin **amylose** – a chain of glucose molecules joined by α-1,4-glycosidic bonds which, by hydrogen bonding, form a helix. It is this helix which holds and forms a complex with iodine when we test for starch  	Insoluble in water, therefore good **storage** compound e.g. in stroma of chloroplasts The helix forms a compact shape which allows tight packing and is therefore an excellent storage molecule.
	amylopectin – glucose molecules joined by α-1,4-glycosidic bonds **but** after every 25 glucose molecules adjacent chains are connected by α-1,6-glycosidic bonds i.e. amylopectin is branched. 	Amylopectin has many protruding ends (glucose molecules) which can be hydrolysed rapidly – allows rapid release of glucose to provide energy via respiration. Starch from different sources is unique. Each source has characteristic proportions of amylose and amylopectin and the lengths of these two molecules differ. Thus, microscopic analysis of a starch grain can be used to identify which type of plant it came from.
Glycogen – main storage polysaccharide of animal and fungal cells.	Similar structure to amylopectin (in that it is a polymer of α-glucose) of starch but has many more branches and the branches are shorter. Glycogen is even more compact than amylopectin.	**Compact storage** molecule in mammalian liver and in fungal cells and can be broken down to release glucose. The structure of glycogen allows faster hydrolysis than starch which is important as animals may need emergency glucose faster than plants.
Cellulose – structural polysaccharide in plants.	Long unbranched chains of glucose linked by β-1,4-glycosidic bonds. The individual chains are then linked to each other by hydrogen bonds. These are formed into **strong** microfibrils. 	Hydrogen bonding prevents water entering the molecule. Cellulose is therefore resistant to enzyme hydrolysis which makes it an excellent **structural** polysaccharide. Cellulose cell walls provides protection to all plant cells. Humans cannot digest cellulose but herbivores have bacteria and protoctists in their digestive system which produce cellulase (β-1,4-glycosidase). The long unbranched fibrous structure provides great mechanical strength.
Chitin – structural polysaccharide found in hard exoskeletons of all arthropods and in hyphal walls of many fungi.	Made of glucosamine units (glucose + amino acid) and is linked by β-1,4-glycosidic bonds. 	The presence of the amino group causes even more hydrogen bonding between the chains than in cellulose. Chitin is therefore an extremely **resilient** and **tough** polysaccharide.

Testing for Carbohydrates

The most common tests for carbohydrates are summarised in Table 3.

Table 3.Common carbohydrate tests

Test	Reagent	Method	Positive result
Starch	Iodine	Add 2-3 drops of iodine	Blue/black precipitate (ppt) forms
Reducing Sugar e.g. glucose fructose maltose	Benedicts' reagent	Add volume of Benedicts' reagent = volume of test solution. Mix. Heat to 70°C (Do not boil because this would split a disaccharide e.g. sucrose into reducing sugars (glucose and fructose) and give a false positive test)	Solution turns from blue to pale green to yellow to orange to brick red ppt of copper (I) oxide. The intensity of the colour, which can be measured accurately using a colorimeter, indicates how much reducing sugar was present.
Non-reducing sugar e.g. sucrose	Benedicts' reagent	To $2cm^3$ test solution add $1cm^3$ dilute HCl. Boil. Cool and neutralise with excess NaOH. Repeat test for reducing sugar	Brick red ppt

Functions of carbohydrates: a summary

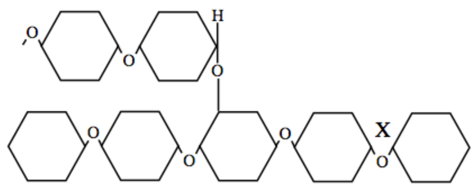
1. Immediate respiratory substrates e.g. glucose
2. Energy stores e.g. glycogen in mammals
   starch in plants
3. Structural components e.g. cellulose in plant cell walls
   chitin in arthropod exoskeleton
   pentose sugars - ribose and deoxyribose are components of RNA and DNA respectively.
4. Metabolites i.e. intermediates in biochemical pathways
5. Cell-to-cell attachment molecules e.g. combined with proteins to form glycoproteins or lipids to form glycolipids on plasma membrane
6. Transport e.g. sucrose in plant phloem tissue

Digestion of polysaccharides

	Stage	Enzyme
Starch	Starch → Maltose Maltose → Glucose	salivary and pancreatic amylase. α amylase breaks 1-4 links randomly. β amylase breaks alternate 1-4 links. Maltase in intestinal juice
Glycogen	Glycogen → Glucose	β cells in islets of Langerhans secrete glucagon which activates enzymes for glycogenolysis
Cellulose	Herbivores have bacteria and protoctists in their digestive systems	Cellulase (β-1,4-glycosidase)

Practice questions

1. The diagram shows part of a starch molecule



(a) Name the type of bond found at position X (1 mark)
(b) Name the reaction which formed this bond (1 mark)
(c) Explain how the structure of this molecule is related to its function (2 marks)

2. Outline a biochemical test which you could use to distinguish between a solution of glucose and a solution of sucrose (3 marks)

1.1K Carbohydrates

Make notes on carbohydrates by answering the following questions

1. Broken down, what does the word carbohydrate mean?

2. Monosaccharides are often called simple sugars. What is a monosaccharide and why are they soluble in water?

3. How are monosaccharides classified?

4. Glucose and fructose are both hexose monosaccharides, with identical molecular formulae. Why are they classed as different sugars and have different properties?

5. Draw the straight form and ring structure form for glucose. When do they exist in their different forms? Label the carbon atoms 1 – 6.

6. Disaccharides are formed when two monosaccharides undergo a condensation reaction. Below are some common disaccharides, complete the table.

Disaccharide	**Monosaccharide 1**	**Monosaccharide 2**	**Function**
Maltose			
Lactose			
Sucrose			

7. Draw a diagram to show the formation of maltose. Explain why this is known as a condensation reaction. What is the name of the bond that forms?

8. Glucose comes in different forms, namely, α andβ. Draw these molecules and highlight the differences.

9. In polysaccharides, monosaccharides are joined together to form polymers. Four common polysaccharides are all formed from glucose and yet they have diverse structural properties and functions. For each of the following, describe how they are formed, their structure and how this relates to their function:
    - Starch
    - Glycogen
    - Cellulose
    - Chitin

10. What role does hydrogen-bonding play in helping to maintain the structure of the above polysaccharides?